RESEARCH INFORMATION BULLETIN

A series of reports by the Naval Medical Research Unit - Dayton

No. 11-46   Date: 15 September 2011

Predicting Individual Differences in Response to Sleep Loss

Fatigue resulting from poor or insufficient sleep is commonplace in the modern military. It is an everyday threat, from the challenges of rigorous training to the demands of continuous combat operations. Fatigued warfighters display slowed physiological and cognitive reaction times, decreased vigilance, memory problems, and increased mistakes during even routine decision making. Multiple attempts have been made to manage and mitigate these effects through fatigue prediction modeling and optimized crew scheduling. However, current fatigue models have key drawbacks. First, the most commonly used models assume equal susceptibility to, and impact of, fatigue across individuals. A growing body of research suggests that large, stable individual differences in fatigue susceptibility exist. Second, the data used to build these models is based heavily on total sleep deprivation and not the more typical chronic, intermittent sleep restriction associated with military operations. The ability to objectively measure and predict an individual's level of fatigue, especially chronic fatigue associated with high tempo operations, is critically needed. Identifying stable and predictive measures, and incorporating them into fatigue and performance modeling tools, could greatly improve crew performance, mission success, and ultimately warfighter safety.

Previous work at this laboratory sought to validate the use of non-invasive eye-tracking (PMI FIT 2000) and cognitive (FlightFit) performance tests to detect individual impairment due to fatigue in a military population (DTIC ADA522106). Over the course of 25 hours of continual wakefulness in a laboratory setting, eye-tracking measures of saccadic velocity (eye movement speed) and cognitive performance (attention shifting) were highly sensitive to the effects of fatigue. More importantly, these tools were able to identify an individual's susceptibility to performance decrements associated with fatigue, a capability not available with tools based on average group performance. While these results were promising, further evaluation was needed to evaluate the tools under more operationally realistic conditions of chronic fatigue.

A recently completed study was conducted to further validate eye-tracking and cognitive performance measures for detecting individual differences in fatigue resistance under chronic, cumulative sleep loss conditions. The study employed a chronic sleep restriction protocol, in which 24 active duty military members participated. Two days of rested baseline performance were collected followed by four experimental days in which four hours of sleep were allowed each 24-hour period. Five testing sessions occurred every four hours throughout experimental days, with the first and last tests starting at 0700 and 2330, respectively.

Significant fatigue effects were observed on multiple components of the eye-tracker and on a flight simulator task (cognitive performance data analyses are ongoing). Specifically, reaction time, pupil diameter, pupil constriction amplitude (from a light flash), saccadic velocity, and a composite flight simulator performance measure were found to be increasingly affected by cumulative fatigue. Analyses also revealed significant individual differences across time for saccadic velocity and flight simulator performance. Three clusters of participants tended to emerge in the individualized analyses. Approximately one-fifth of participants were highly resistant to fatigue-related performance effects, showing no significant performance decrements relative to baseline across the four days of sleep restriction. A nearly equal proportion was highly susceptible to such effects, showing rapid and dramatic performance decrements. The remainder, slightly more than half, could be characterized by a pattern of results in which sleep restriction produced steady, moderate performance decrements over the four days. Highly resistant and highly susceptible individuals, though relatively less common, are important to identify. Highly fatigue resistant individuals would be under-utilized if schedulers rely upon current group-based predictive modeling tools, while highly susceptible individuals would present a prediction risk. Better categorization, whether through strict individual prediction, or via assignment to such groups as described, can lead to more accurate performance prediction and ultimately to safer, more efficient utilization of manpower resources.

These preliminary results are similar to patterns of performance resulting from acute fatigue previously established in this lab. Stable individual differences in fatigue responses are present in both acute and chronic sleep loss conditions, and at the gross level, these responses appear highly similar. However, closer analyses of the data reveal several important distinctions between acute and chronic fatigue responses. For example, under acute fatigue conditions, saccadic velocity was the only interpretable eye-tracking measure; under chronic fatigue, several pupil characteristics were also significant. These results suggest that, while related, the effects of chronic and acute fatigue are not physiologically identical. The common assumption that the effect of a few days of chronic sleep restriction is equal to the effect of one night of total sleep loss is not supported by these results. This distinction will be integral to building the next generation of fatigue modeling software and highlights the need for dynamic predictive models that account for such qualitative differences between types and timing of sleep loss.

Studying realistic, chronic fatigue conditions on an individual level is a step in the right direction for operational research. The ultimate goal of this line of research is the development and transition of individualized predictive fatigue models which improve upon the predictive accuracy of current tools, increasing the safety and efficiency of crew scheduling. To achieve this goal, critical components to the fatigue puzzle such as knowing how individuals *recover* from acute and chronic fatigue, must be quantified. Future work will address these gaps.

For more information contact Dr. Joe Chandler at (937) 938-3902, joseph.chandler@wpafb.af.mil.

REPORT DOCUMENTATION PAGE

1. REPORT DATE (DD MM YY) 20 09 11	2. REPORT TYPE Research Information Bulletin	3. DATES COVERED (from – to) 1 Jan 2009 – 31 Dec 2011

4. TITLE
Predicting Individual Differences in Response to Sleep Loss

5a. Contract Number:
5b. Grant Number:
5c. Program Element Number:
5d. Project Number:
5e. Task Number:
5f. Work Unit Number: 71003/70803

6. AUTHORS
Joseph F. Chandler, PhD

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Medical Reserach Unit – Dayton
2624 Q St., Bldg. 851, Area B
Wright-Patterson AFB, OH 45433

8. PERFORMING ORGANIZATION REPORT NUMBER
Report No. 11-46

8. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
Bureau of Medicine and Surgery Medical Development Program
Department of the Navy
2300 E Street, NW
Washington, DC 20372-5300

10. SPONSOR/MONITOR'S ACRONYM(S)
BUMED

11. SPONSOR/MONITOR'S REPORT NUMBER(s)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Fatigue resulting from poor or insufficient sleep is commonplace in the modern military. Previous work at this laboratory sought to validate the use of non-invasive eye-tracking (PMI FIT 2000) and cognitive (FlightFit) performance tests to detect individual impairment due to fatigue in a military population (see technical report: DTIC ADA522106). Over the course of 25 hours of continual wakefulness in a laboratory setting, eye-tracking measures of saccadic velocity (eye movement speed) and cognitive performance (attention shifting) were highly sensitive to the effects of fatigue. A recent study further validated eye-tracking and cognitive performance measures for detecting individual differences in fatigue resistance under chronic, cumulative sleep loss conditions. The study employed a chronic sleep restriction protocol, in which four hours of sleep were allowed each 24-hour period. Significant fatigue effects were observed on multiple components of the eye-tracker and on a flight simulator task (cognitive performance data analyses are ongoing). Analyses also revealed significant individual differences across time for saccadic velocity and flight simulator performance. Studying realistic, chronic fatigue conditions on an individual level is a step in the right direction for operational research. The ultimate goal of this line of research is the development and transition of individualized predictive fatigue models which improve upon the predictive accuracy of current tools, increasing the safety and efficiency of crew scheduling.

15. SUBJECT TERMS
X fatigue, sleep loss, acute sleep deprivation, chronic sleep restriction, saccadic velocity, individual differences

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	18a. NAME OF RESPONSIBLE PERSON
a. REPORT UNCL	b. ABSTRACT UNCL	c. THIS PAGE UNCL	UNCL	3	Commanding Officer
					18b. TELEPHONE NUMBER (INCLUDING AREA CODE) COMM/DSN: 937-938-3872 (DSN: 798)

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18